WEST AFRICAN COCOA RESEARCH INSTITUTE

QUARTERLY PROGRESS REPORT

No. 41

TAFO, GOLD COAST.

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WEST AFRICAN COCOA RESEARCH INSTITUTE
TAFO

FORTY-FIRST QUARTERLY REPORT : JANUARY-MARCH, 1956

SENIOR STAFF

Director : : :	J. Lamb
Secretary : : :	G. H. Neal (on pre-retirement leave 28th March)
Acting Secretary : :	R. J. Webb (arrived 6th March)

TAFO STATION

Division of Entomology :	D. J. Taylor F. Raw P. B. Cornwell (on leave) P. F. Entwistle Helen M. Entwistle (appointed 15th March)
Division of Pathology :	W. T. Dale A. L. Wharton (on leave) G. Usher A. Attafuah
Division of Botany :	A. D. McKelvie
Division of Soil Science and Chemistry :	T. A. Rohan E. Margaret Holden (on leave 23rd March)
Division of Agronomy :	R. J. Benstead
Guide-Demonstrator : :	F. E. Decker
Station Manager : :	S. E. Ntim-Kwafo

IBADAN SUB-STATION

Acting Officer-in-charge :	J. Nicol
Entomologist : :	R. G. Donald
Pathologists : :	R. M. Lister (on leave 28th February) J. M. Thresh

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MANAGING COMMITTEE

The nineteenth meeting of the Managing Committee was held at Tafo on 15th March, being preceded by a meeting of the Technical Sub-Committee on 13th March.

CACAO VIRUS CONTROL IN NIGERIA

A symposium on cacao virus control in Nigeria was held at Moor Plantation, Ibadan, in February, under the chairmanship of the Acting Officer-in-charge of the Sub-station, Mr. J. Nicol. It was attended by the Sub-station Senior Staff, representatives of the Western Region Department of Agriculture and the Federal Department of Agricultural Research, the Director of the Institute and three other officers from Tafo (Messrs. R.J. Benstead, D.J. Taylor and W.T. Dale).

Although untreated areas of 'mass infection' constitute an obvious threat to uninfected cacao farms throughout the Western Region, treatment is confined at present (for political and economic reasons) to attempts to eliminate small centres of infection and seal-off larger ones, of which that near Ibadan is by far the most extensive. Following discussions led by Messrs. R.M. Lister and J.M. Thresh of the Sub-station and Mr. J. Hadland of the Cocoa Survey Division of the Western Region Department, a full exchange of ideas took place. Treated outbreaks in the field were visited, and particular interest was shown in experiments on coppicing as an adjunct to cutting out for cacao virus control. This measure should lead to more economical control within the treated areas. It was agreed that the symposium had served a very useful purpose, and that similar meetings on other subjects should be held at intervals.

STAFF MATTERS

Mr. G.H. Neal went on pre-retirement leave on 28th March, after ten years' service as Secretary of the Institute. We are grateful to the Crown Agents for Oversea Governments and Administrations for seconding Mr. R.J. Webb as Acting Secretary, pending a permanent appointment. Mr. P.B. Cornwell, who is at present on leave, has submitted his resignation. Mrs. H.M. Entwistle has been appointed as temporary Entomologist, to investigate cacao pollination.

After attending the meeting of the West African Inter-Territorial Council, held at Bathurst in January, the Chairman of the Managing Committee and the Director flew on to London for discussions at the Colonial Office on measures to stabilize the Senior Staff position, which is giving cause for concern. As a result, the Managing Committee has been able to offer more attractive conditions of service. Some success has been achieved in recruiting new staff and preserving continuity in important research projects, such as cacao breeding and nutrition.

Mr. Nicol (Acting Officer-in-charge) and Mr. R.M. Lister (Pathologist) of the Ibadan Sub-station visited Tafo in January. After attending the symposium on cacao virus control, Messrs. Taylor and Dale visited cacao projects and experiments in the

Western .../

Western Region of Nigeria. A number of young plants, including some of the Upper Amazon progenies at Apodje (Western Region Production Board), were suffering from the severe dry season. Mr. Benstead also visited some of these centres, and later made a trip to the Northern Region to assess the potentialities for cacao in Kabba and Ilorin Provinces. In January Mr. A.D. McKelvie paid a short visit to Nigeria to select sites for two variety trials, and during late February and March he visited the United Kingdom to attend a four-week course at Harwell on the experimental uses of radio-isotopes. He also took this opportunity to visit Rothamsted Experimental Station, the Cambridge Plant Breeding Institute and a few other Institutions.

VISITORS

The Ibadan Sub-station participated in the arrangements made for the visit of Her Majesty the Queen and His Royal Highness the Duke of Edinburgh to Moor Plantation. A demonstration of some aspects of the Institute's work was arranged.

The Tafo Station has had even more visitors than usual, some of these coming to help out the Institute in various ways. Mr. T.N. Hoblyn of East Malling Research Station arrived towards the end of March for a stay of some weeks, during which he will advise on existing and proposed field experiments. Mr. C. Hatherley of Messrs. Raw Products Limited spent about ten weeks with us during the quarter, to familiarize himself with the work in progress. A free-lance journalist-photographer, Miss D. Hope-Smith, took a number of photographs depicting life and work at the Institute, which should provide publicity to assist recruitment. Messrs. Cadbury Brothers are kindly assisting in the preparation of a booklet incorporating a selection of these photographs. Miss H.M. Richards of the Town Planning Division, Gold Coast Ministry of Local Government, has submitted suggestions on housing and lay-out of the residential area. Other visitors have included Mr. J. Hadland (Western Region Department of Agriculture, Nigeria), Mr. P. Mulholland (Northern Region Department of Agriculture), Mr. W.A. Dillsworth (Acting Secretary for Training and Recruitment, Sierra Leone), Dr. F.B. Sands (Director of Agriculture, Liberia), Miss M.A. Hewlett and Dr. B.J. Harris (University College of the Gold Coast), Messrs. H. Helfritz and R. Vogler (German Institute of Foreign Relations), Mr. P. Cadbury (Messrs. Cadbury Brothers) Mr. J.H. Stapley (Messrs. Plant Protection Ltd.), Dr. E. Evans (Messrs. Fisons Pest Control Ltd.) and Mr. A.V. Coombs (British Sulphate of Copper Association Ltd.). In addition to the usual parties of Agricultural Survey Officers and students, we have received the Chairman and seven members of the Gold Coast Cocoa Marketing Board, a party of delegates to the First West African Science Association Conference and five members of the Commonwealth Parliamentary Delegation.

MANAGEMENT AND MAINTENANCE

At Tafo, improvements and repairs have been effected to several Senior Staff bungalows and to the Rest House. A large number of Junior Staff quarters have been repaired or re-decorated. The new laboratory block at Ibadan is now complete, and furniture and benches are being installed. Ten

insectaries .../

insectaries and a virus transmitting room have been completed and water laid on in each.

The average daily production and consumption of potable water at the Tafo Station were as follows :-

	Production	Consumption
January ..	25,874 gallons	25,145 gallons
February ..	28,507 "	24,383 "
March ..	23,339 "	19,926 "

The usual seasonal increase in consumption was apparent in February and March (compare 37th Quarterly Report).

CROP DELIVERY

Harvesting was completed by 13th February, crop harvested during the quarter being less than 7% of the total, compared with 12% for the same period last year. The percentage of discarded pods showed the normal seasonal rise associated with the branch crop. The overall yield of pods from the recorded areas of the Old Station showed an increase of 9.2% over that for the 1954-55 crop season, whilst yield per acre of dry cocoa was up by 16.4%. The number of pods required to produce one pound of dry cocoa fell from 11.2 in 1954-55 to 10.6, and pod discards from 8.9% to 7.8%, these two factors explaining the greater percentage increase in yield per acre than in total pods.

SWOLLEN SHOOT DISEASE INCIDENCE

The numbers of trees removed during treatment for swollen shoot disease were as follows :-

Station		Jan.	Feb.	Mar.	Total
Old Station *		51	13	37	101
Square Mile	Diseased	180	332	173	685
	Suspects & Contacts	92	201	77	370
Adonkwanta		-	10	-	10
Akwadum		-	-	-	-
Nankese		-	-	-	-
Kukua		8	-	10	18
Koransang		4	-	21	25

*Excluding 46 seedlings removed from replantings made since 1945.

... Losses of mature trees on the Old Station from causes other than swollen shoot amounted to 29.

OUT-STATIONS .../

OUT-STATIONS

Overhead shade was drastically reduced at Adonkwanta, Kukua and Nankese by removal or ring-barking of dense-crowned species such as Pseudospondias, Avocado Pear and Saman. Drought effect was particularly severe at Kukua, where the rainfall from 1st November to 29th February amounted to only 4.48 inches. Capsid attack continues to be severe on areas of poor establishment on all sub-station farms, and it is obvious that the present method of control by spray-painting with DDT emulsion is not proving effective.

UPPER AMAZON SEED

Totals of 2,696 F2 and 12,050 F3 pods have been sent during the season to the Agricultural Departments of Eastern and Western Nigeria and the Southern Cameroons. A total of 5,510 F2 pods has been supplied to the Gold Coast Department of Agriculture.

METEOROLOGY

Station	Rainfall in inches				Wet days			
	Jan.	Feb.	Mar.	Total	Jan.	Feb.	Mar.	Total
Tafo Station	0.89	0.61	6.40	7.90	2	3	13	18
" 18-yr mean	1.57	3.83	6.06	11.46	3.6	7.2	11.8	22.6
Adonkwanta	0.46	1.92	6.75	9.13	2	5	10	17
Akwadum	.60	3.90	4.11	8.61	1	5	15	21
Nankese	-	4.39	6.25	11.64	-	7	10	17
Kukua	-	1.33	5.46	6.79	-	3	7	10
Koransang	0.20	2.00	5.97	8.17	1	4	10	15

RESEARCH WORK

Some of the more interesting developments described in this report are as follows :-

(a) A baobab tree (Adansonia digitata L.) in British Togoland has proved to be infected by a virus so far indistinguishable from one in cacao nearby (p.6).

(b) A plant in the Malvaceae has proved susceptible to the New Juaben cacao virus (p.6).

(c) Completed yield records for the 1955-56 crop season show that spraying with copper fungicides has reduced losses from black pod disease in trials at Bunso; carbide-Bordeaux mixture was most promising, especially when associated with frequent picking and applied according to a schedule based on seasonal incidence (p.11).

(d) .../

(d) Experiments on the control of capsids by gamma BHC applied as a fog, using a 'Swingfog' unit, have given promising results (p.12).

(e) This season, unlike last, Upper Amazon trees now seven years in the field have given most cocoa per acre at the widest spacing, 12' x 12' (p.16).

(f) The polythene sheet method of cacao propagation has been further simplified and its efficiency increased by rooting and hardening the cutting in the same basket (p.17).

(g) Investigations into the natural pollination of cacao have been revived (p.18).

TAFO STATION

1. VIRUS RESEARCH

(a) Host Range of Cacao Viruses

Fifteen trees of Adansonia digitata L. are now known to harbour viruses capable of infecting cacao, but only one of these is in a cacao area; that at Wusuta in British Togoland, referred to in the previous report. The virus from this tree has produced symptoms in cacao test plants indistinguishable at present from those of the Kpeve-type isolate derived from naturally infected cacao nearby.

A virus of the New Juaben type has been isolated from a regenerating stump of Ceiba pentandra Gaertn., growing in a large swollen shoot outbreak in cacao near Adawso. Three out of twenty cacao test plants have developed infection. This is the first example of natural infection in Ceiba disclosed for several years, but as in previous cases there is no knowing whether infection has spread from Ceiba to cacao or vice versa.

Professor H.G. Baker of the University College of the Gold Coast has kindly clarified the position with regard to spineless types of Ceiba (see previous report). Relatively small stature, poorly developed buttresses, rather broad unserrated leaves and a spineless trunk are characteristics derived from C. guineensis A. Chev., one variety of which (clausa Ulbrich) has indehiscent pods. Trees with some of these characters found in plantations and around villages in the Northern Territories, and occasionally elsewhere in the Gold Coast, are hybrids between C. guineensis and C. thonningii A. Chev. (probably conspecific with C. pentandra). Those tested so far have proved susceptible to the New Juaben cacao virus.

In laboratory tests, Wissadula amplissima var. rostrata R.E. Fries has proved susceptible to the New Juaben virus. This is the first infection obtained in the Malvaceae, a family not included in the order Tiliales by the 'Flora of West Tropical Africa'. But the relationship between the Malvaceae and families comprising the Tiliales is undoubtedly close; so much so that some authorities group all together

as .../

as Malvales. Bombax buonopozense P. Beauv. has been artificially infected with the Adansonia virus A.D.7, and Heliocarpus popayanensis with the cacao viruses from Bosomtwe and Offa Igbo.

(b) Insect Transmission Studies

The New Juaben cacao virus has been experimentally transmitted, very occasionally, by both nymphs (first or second instar) and young adults of Pseudococcus njalensis Laing given only ninety minutes' access to infected plants.

(c) Classification of Viruses and Virus Strains

Further protection tests have shown that the cacao virus from Bisa is not closely related to those from Pamen or Mampong; nor is the last-named closely allied to the ones from Sedi Nkawie or Nkawkaw. The Kpeve virus from British Togoland is unrelated to that from Yaakase in the Ivory Coast. The Adansonia virus isolates AD.7, 14 and 36 are not related to the Bisa, Mampong and New Juaben cacao viruses. Cacao plants infected with these three Adansonia isolates showed no obvious change in symptoms when 'challenged' with the Kpeve virus. This suggests close relationships; but the symptoms of the four viruses are similar and all show variations in virulence from plant to plant, so it is difficult to be certain that no protection has occurred. Amongst the naturally occurring viruses of Cola chlamydantha K. Schum., that from Anibil is not closely related to the ones from Aiyim and Bakukrom.

The symptom sequences are being carefully followed in batches of plants infected, as dissected beans, with sixteen Gold Coast or Nigerian cacao virus isolates. It is intended to take growth measurements to provide an estimate of relative virulence.

(d) Attempted Mechanical Transmission

A method described by Yarwood (Plant Dis. Reptr, 37, p.501, 1953), which he used successfully for transmitting a virus of apples, has been tried, with modifications, on cacao. Discs from leaves of young infected seedlings were cut out with a cork borer, stacked on top of each other, trimmed to a straight edge with a razor blade and immediately rubbed on the leaves of test plants. These were young cacao and tobacco seedlings, which had their leaves sprayed with K_2HPO_4 and dusted with celite before rubbing with the discs. There were no transmissions.

(f) Chemical Detection of Cacao Virus Infection

The investigation on chemical aspects of the Tinsley-Usher colour test has now been concluded and the results written up for publication in the Biochemical Journal.

The test based on the reduction of triphenyl tetrazolium chloride has been used on sections from the stems of young seedlings and from twigs of mature trees. The results have been unsatisfactory, and it is not proposed to continue this investigation.

(h) .../

(h) Resistance to the New Juaben Virus

The cuttings in the first replication of the experiment to compare tolerance and resistance in fifty Iquitos-type F1 seedling trees have been scored for both characters. There is a suggestion that they may be correlated. All five cuttings became infected, except in the following clones, the figures in brackets indicating the number that did so :-

T17/2628, 1132, 1159, 1130, 2655, 434 (4); 448, 2651, 445, 433 (3); 1219, 2626, 359, 1160 (2); 435 (1).

Three other replications of this experiment are in progress.

2. MEALYBUG STUDIES

(f) Mass-breeding of Mealybugs

No further improvement has been made in the breeding technique since the previous report, and no visible change has been observed in the establishment of ants. Although poor sprouting of the potato host plants has been reflected by low mealybug populations, the 'culturing room' has provided a useful source of Pseudococcus njalensis for critical transmission experiments, in which it was imperative that any chance of prior contamination with virus should be eliminated. Further supplies for experiments of this type have been obtained by establishing a 'nursery' of saplings of the myrmecophyte Ganthium glabriflorum Hiern.

3. STUDIES ON BLACK POD DISEASE

(a) Fungicide Control Trials

As relatively few pods have been harvested during the quarter from the two spraying trials at Bunso and the 1955-56 crop season is now complete, records for the entire season are summarized in the Tables (opposite and overleaf). The only noteworthy features of the current quarter's figures are the low incidence of black pod disease (4% of the 3,387 pods harvested in Trial I) associated with season, and the high proportion (61%) of pods damaged by rodents (compare 37th Quarterly Report).

The season's figures have not yet been statistically analysed and they will be considered in greater detail in the Annual Report for 1955-56. The following comments may, however, be made :-

(i) As in previous seasons, the weekly harvested plots in Trial I have given more pods than those harvested monthly (57% of the total); but the difference was slight in Trial II, due to the Blitox-sprayed, monthly harvested trees yielding many more pods than the weekly harvested ones.

(ii) .../

TRIAL I - YIELDS IN PODS PER TREE 1955-56

Fungicide	Frequency of harvesting	Mean yield	%*	Frequency of application	Mean yield	Undamaged %	Black pods %	Rodent damaged %	Others damaged %	Discarded %	Black pod discards %
Unsprayed	Weekly	57.8	61.8	-	57.8	56.0	20.4	16.6	7.0	40.0	17.1
	Monthly	35.7	38.2	-	35.7	39.5	35.2	19.1	6.1	56.4	31.4
Cupride-Bordeaux Mixture	Weekly	50.1	57.2	Frequent	53.5	71.1	5.2	18.9	4.8	27.1	3.5
				Monthly	46.6	77.3	6.4	11.0	5.3	20.2	5.5
	Monthly	37.5	42.8	Frequent	33.4	78.3	5.7	11.3	4.7	26.4	5.3
				Monthly	41.7	54.8	11.5	27.9	5.8	42.2	10.1
Ordinary Bordeaux Mixture	Weekly	57.0	50.2	Frequent	61.1	74.6	6.7	14.0	4.6	22.9	5.8
				Monthly	52.9	61.6	9.5	20.7	8.2	34.9	8.6
	Monthly	56.5	49.8	Frequent	64.6	56.8	11.0	24.0	8.2	39.7	10.9
				Monthly	48.3	61.2	15.4	17.4	6.0	34.0	12.1
Perenox	Weekly	49.5	60.0	Frequent	57.1	66.8	6.4	20.5	6.3	30.9	5.6
				Monthly	42.0	63.2	12.7	20.4	3.7	35.9	10.7
	Monthly	33.0	40.0	Frequent	34.8	64.9	11.9	17.8	5.4	32.7	10.8
				Monthly	31.2	61.2	17.4	16.6	4.8	34.6	15.5

* See footnotes for Trial II (over).
† 24 applications per annum - weekly, fortnightly or monthly, depending on the seasonal incidence of black pod disease.

TRIAL II - YIELDS IN PODS PER TREE 1955-56

Fungicide	Frequency of harvesting	Mean yield	%*	Frequency of application	Mean yield	Undamaged %	Black pods %	Rodent damaged %	Others damaged %	Discarded %	Black pod discards %
Unsprayed	Weekly	34.0	54.7	-	34.0	67.5	17.0	11.0	4.4	28.0	13.9
	ϕMonthly	28.1	45.3	-	28.1	54.5	33.1	8.9	3.4	40.7	29.6
Perenox	Weekly	31.1	51.8	Fortnightly	32.6	71.8	11.1	13.4	3.7	24.8	8.8
				ϕMonthly	29.6	82.2	9.1	5.5	3.2	14.0	7.2
	Monthly	28.9	48.2	Fortnightly	27.7	71.9	12.2	11.8	4.1	25.2	10.2
				Monthly	30.1	57.9	24.3	13.2	4.6	38.3	21.6
Blitox	Weekly	25.4	44.4	Fortnightly	29.7	69.4	16.9	9.4	4.3	28.2	14.9
				Monthly	21.2	72.2	16.6	8.6	2.7	25.1	14.8
	Monthly	31.8	55.6	Fortnightly	36.0	65.8	14.8	13.7	5.7	31.5	12.6
				Monthly	27.7	68.3	17.1	11.3	3.2	30.3	16.1

* This percentage is based on the total number of weekly and monthly harvested pods, the others on the total number of pods for each treatment.

ϕ In both harvesting and spraying treatments 'monthly' means every 28 days.

(ii) Weekly harvesting again reduced the incidence of black pod disease - in the unsprayed plots by almost half (from 35.2 to 20.4% for Trial I, and from 33.1 to 17.0% for Trial II).

(iii) Unlike last season, spraying with copper fungicides reduced the incidence of black pod disease. In Trial I, carbide-Bordeaux mixture gave the best results, especially if applied 'frequently' (weekly or fortnightly) during the first part of the crop season (when the disease is most prevalent) and monthly thereafter. As would be expected, the lowest incidence (5.2%) was in plots harvested weekly and sprayed 'frequently'; but with carbide-Bordeaux good control was obtained from 'frequent' spraying and monthly harvesting (5.7% incidence) or regular monthly spraying throughout the year and weekly harvesting (6.4%). Comparable control was given by ordinary Bordeaux mixture (6.7%) and Perenox (6.4%), but only when applied 'frequently' and combined with weekly harvesting. In Trial II, Perenox did not give quite such good results, even when applied at regular fortnightly intervals and combined with weekly harvesting, and Blitox was less effective.

On the basis of these trials only carbide-Bordeaux and Perenox merit further consideration, the former because of its effectiveness and persistence, the latter because it combines reasonably good fungicidal properties with ease of preparation. Perenox has been applied hitherto at 0.3%, and the use of a more concentrated suspension is under consideration.

The majority of black pods, in all treatments, were discarded as worthless. Rodents were the other main cause of loss and their depredations warrant serious attention; not only do they remove the beans from some pods, but the superficial damage they cause to many lets in various pod-rotting fungi. The incidence of rodent damage varied greatly from plot to plot, but showed no obvious relation to spraying or harvesting treatments; nor did these treatments have any apparent effect on losses from other causes.

4. CAPSID STUDIES

(a) Capsid Pocket Regeneration Experiment

Regular assessment of growth and regeneration of the coppiced trees is being made. Capsid control has been achieved by regular insecticidal treatment but some damage by psyllids and Earias sp. has occurred.

Insecticidal Studies

Investigations on the toxicity, mode of action and persistence of BHC and DDT are continuing, using capsids reared by the laboratory method described in the previous report as test insects.

Toxicity .../

Toxicity of BHC and DDT to Capsids

Further tests have confirmed that at concentrations hitherto used in field trials, i.e. 0.25% BHC and 2.5% DDT, a more efficient knock-down is achieved with BHC.

Persistence of Insecticides

Experiments to investigate the persistence of BHC and DDT deposits on cacao foliage under field conditions are being continued, using capsid nymphs as test insects.

Fumigant Action of BHC

It has been shown that BHC has a strong fumigant toxicity to capsid nymphs and adults. This was demonstrated in the following way. Cacao leaves were sprayed to drip point with 0.25% BHC and the spray deposit allowed to dry. Distantiella theobroma Dist. nymphs and adults were then caged over the leaves without being in contact with the leaf surface. At 30°C., exposure for 30 minutes killed all adults and exposure for 2 hours killed all first-instar nymphs. No similar fumigant action has been demonstrated for DDT.

It is considered that the fumigant action of BHC has an important bearing on its application to capsid control, and together with its higher toxicity may explain the superiority to DDT observed in field trials conducted by W.A.C.R.I. and the Gold Coast Department of Agriculture. When spraying mature cacao under field conditions it is virtually impossible to obtain complete cover, so the use of an insecticide with a fumigant action has obvious advantages.

Efficiency of Fog Application of BHC

This demonstration of the importance of fumigant action in the control of capsids by BHC has re-opened the possibility of using a fogging method of application. Trials carried out eighteen months ago using a proprietary insecticidal solution, based on DDT, in the "Swingfog" pest control unit gave a very poor kill and the method was subsequently abandoned. Using the same unit and an insecticidal mixture consisting of 1 part BHC concentrate containing 20% of the gamma isomer (Gammalin 20, Plant Protection Ltd.) and 3 parts diesel fuel, very good results have been obtained. The recent experiments were carried out in mature cacao, using adults and nymphs of Distantiella theobroma Dist. as the test insects. The capsids, in 16-mesh wire-netting cages, were placed in the trees 12-15 feet above ground level and down wind to the line of movement of the operator.

A 100% kill of adult capsids which were placed in the fog ten feet from the generator was obtained after 2½ hours; nymphs in a similar position were dead within 12 hours. At 60 feet, a 100% kill of adults was obtained in 20 hours, and of nymphs in 36 hours. In an experiment to find the maximum distance at which a kill may be obtained, series of cages were set up at 60, 80, 100 and 120 feet from the operating line. A 100% kill of adults was recorded at 60, 80 and 100 feet 20-24 hours after the application; approximately

60% .../

60% of nymphs were killed under the same conditions. At 120 feet, only 60% of adults were dead after 24 hours. Thus, a reasonably good insecticidal effect can be expected up to a distance of 100 feet, though it will, of course, depend on prevailing weather conditions.

To obtain some information on the quantity of insecticide required, a fog application was made to an area of 10½ acres of mature cacao which was in lines and at a regular spacing of 10' x 10'. In order to estimate the efficacy of the application, 20 cages containing 300 capsids were set up throughout the area. During application the operator walked through the cacao along parallel lines at approximately 100-foot intervals, and completed the job in 35 minutes. Twenty-four hours later a 68% kill of adults and a 31% kill of nymphs were recorded. 3,320 cc. of the insecticidal mixture was used, and as this contained 830 cc. of the Gammalin 20 concentrate, 79 cc. of concentrate was used per acre. A similar trial was carried out later through the area, in which the operator walked along parallel lines at approximately 50-foot intervals. This application took 55 minutes and 6,065 cc. of the insecticidal mixture was used. This is equivalent to 144 cc. Gammalin 20 per acre. After 24 hours a 95% kill of adults and a 43% kill of nymphs were recorded. The quantity of Gammalin 20 used may be compared with the 568 cc. used in the "4 oz. gamma BHC in 5 gallons per acre" low-volume liquid treatment.

Thus it appears that fog application of BHC is a very effective and economical method of capsid control for large areas of mature cacao, because of the rapidity with which it can be effected and the very efficient conversion of the concentrate to a widely dispersed and highly toxic form.

Ovicidal Properties of BHC

A series of exploratory laboratory experiments has been conducted to find out whether gamma BHC is ovicidal. The treatments have consisted of mist-blowing, hand-painting or spray-painting with aqueous emulsions at appropriate concentrations, as indicated in the Table. The eggs, obtained by caging adult capsids on young seedlings, were treated *in situ*. Care was taken when making the applications to thoroughly wet the whole of the bark, thus ensuring that the filaments of all eggs received the insecticidal solution. About one third of the egg-bearing seedlings in each batch were left untreated to serve as controls. The hatching rates for treated and untreated eggs were as follows :-

Treated .../

	Treated	Untreated
Mist-blown with 0.25% emulsion	90%	100%
" " 0.5% "	109%	100%
" " 1.0% "	57%	93%
Hand-painted with 0.25% "	66%	43%
Spray-painted with 1% "	38%	16%
" " 2% "	45%	
" " 1% "	66%	54%

The experiments were carried out in the order indicated above, and not simultaneously. As the hatching rate for normal untreated eggs was lower, probably for climatic reasons, during the latter part of the work, results from one experiment are not strictly comparable with those from another. Interpretation of the results is also complicated by the lower hatching rates for untreated controls compared with treated seedlings in the hand- and spray-painting experiments. As all seedlings were kept in insectaries after treatment this cannot be due to the differential action of parasites or predators, but may be explained by untreated seedlings being considerably fewer than treated, so that failure of the eggs on a single seedling to hatch unduly weighted the final figure.

Taking these factors into account, it is considered that hand- and spray-painting treatments have not affected the hatching rates. A similar conclusion may be drawn from the two lower rates of mist application. The results for 1% mist application may suggest that this treatment has reduced the hatching rate; but it is considered that if, in fact, BHC were ovicidal, a much higher kill would be expected. Consequently, it is tentatively concluded that this insecticide has no pronounced, if any, lethal effect on capsid eggs. More comprehensive experiments are being continued on this line.

(f) Capsid Ecology

Estimation of Populations by Egg Counts

Experiments to investigate the possibilities of capsid population estimation by egg counts, in cacao of seedling to intermediate age, were laid down in January, and it is hoped that they will eventually suggest a relatively simple method of forecasting fluctuations. As these are long-term experiments it is too early yet for judgement to be made, but it seems so far that the size of tissue samples removed for egg counts must be increased. Obviously, the degree of correlation between counts of unhatched eggs and of post-eclosion stages is a measure of the suitability of the sample sizes used, a point well illustrated by amalgamating the results from two contiguous plots at Akwadum, when, due to a doubled sample size, correlation becomes much more apparent.

Preferred .../

Preferred Oviposition Sites

Studies on the vertical distribution of capsid eggs in mature cacao are continuing. Complete trees are felled, their height measured and, for purposes of analysis for egg abundance, the vegetative tissue is divided into five-foot vertical lengths. This investigation is a necessary preparatory one before extending experiments on population estimation by egg counts to mature cacao, having an obvious bearing on the sampling method to be employed. In the plots sampled, the number of eggs per unit length of damaged tissue increased, though not linearly, with height. The determinant factor in this distribution appeared to be light, and eggs were not distributed in proportion to the vertical distribution of available oviposition sites. It is to be expected that egg distribution will vary with tree spacing and with the degree of shading, but the point has yet to be established.

This experiment and the ones discussed in the previous sub-section are yielding incidental information on oviposition preferences for fan and chupon tissue in relation to their availability in cacao of different ages.

Population Build-up after Spraying

In conjunction with the Department of Agriculture, it is hoped to commence work on the rate of build-up of capsid populations after spraying, and on a method of estimating the point at which it is desirable to re-spray these returning populations.

(g) Investigation of Fungi Associated with Capsid Lesions

Dissemination

Investigations on the relationship between capsids and Fusarium decemcellulare Brick are continuing, and an experiment has been laid out to compare capsid lesions and mechanical punctures as entry points for the fungus. Treatments are incorporated to show how long the punctures or lesions remain susceptible to infection.

Attempts are being made to ascertain the abundance of F. decemcellulare spores in the air and on young branches of cacao trees showing no obvious capsid damage. During the last four months 200 Petri dishes containing cassava-dextrose agar have been held open in the cacao on the Old Station for 10 seconds each, and in none has F. decemcellulare developed. Pieces of young branch, 5 cm. long and 6-10 mm. thick, have been collected, each washed with 1 ml. of sterile water, and the washings added to plates of cassava dextrose agar. Of 128 pieces examined 6.4% have yielded F. decemcellulare.

Effect of Environment on Host Reaction

The trial mentioned in the last report is now complete and the figures are being studied. Those analysed

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to date show that growth of fungus in lesions made by pricking with a needle carrying F. decemcellulare is greater than in control pricks. The latter never contained F. decemcellulare, but usually Botryodiplodia theobromae Pat. In all cases except one, F. decemcellulare was isolated from the inoculated plants, along with B. theobromae in some instances. After 10 weeks, lesions in weekly watered plants were larger, though not quite significantly so, than those in daily watered plants. Daily watering has increased the height of the seedlings significantly since the third week of treatment, but the first significant effect of the fungus ($P = 0.05$) is to decrease the number of hard leaves after five weeks.

Cultural Studies

Experiments have continued on the nutrient requirements of F. decemcellulare. It has been shown that microspores develop in agar cultures after 3 days. Using sucrose as a source of carbon, neither magnesium nor potassium is necessary for the production of macrospores, which occurs after 7 days; but phosphorus and nitrogen in the form of NO_3^- are essential. With NH_4^+ as nitrogen source no spores of either type develop on any of the media used. Potassium also is essential to macrospore production if glucose is the carbon source. No macrospores are produced on media without a carbon source, and the absence of sucrose greatly reduces the abundance of spores of both types.

It has been shown that F. decemcellulare produces a thermostable ethanol-soluble wilt-producing toxin when cultured in Richard's solution.

5. EXPERIMENTS ON ESTABLISHMENT AND MAINTENANCE

(a) Establishment Trials

Harvesting has been completed on Trials I and II. In Trial I, trees planted out as basket seedlings again showed superiority over those otherwise established. In Trial II, there is no evidence to date that pruning to confine growth to the first tier of fan branches has had any influence on yield.

(b) Spacing Trials

Owing to the fact that the Agronomist previously in charge of statistical work has resigned, no statistical interpretation of data has been carried out. From a cursory examination the following trends are apparent.

Upper Amazon Spacing and Pruning Trial

In the seventh year in the field the heaviest yield has been from cacao spaced at 12' x 12', thus reversing the figures for the previous crop, when that

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at 8' x 8' yielded best. Yields of dry cocoa per acre, computed at 12 pods per lb., were: 8' x 8' - 382 lb.; 10' x 10' - 423 lb.; 12' x 12' - 454 lb. On the unpruned sections of all treatments yields were very slightly higher than on the pruned.

Amelonado Spacing Trial

The superior performance of the 12' x 12' spacing in 1954-55 was not repeated in the present season, and no obvious correlation between yield and density is apparent.

(d) Comparative Yield Trials of Seedlings and Cuttings

The land has been prepared for the replications scheduled for planting in the long rains, and lateral 'bush' has been removed from the first replication.

(e) Effect of Soil Type on Pod Development and Yield

(f) Methods of Forecasting Yields of Cocoa

(g) Effect of Retention or Removal of Chupons on Rooted Fan Cuttings

(h) Frequency of Picking Experiments

Seasonal data in respect of (e), (f) and (h) are complete and await analysis. Normal routine treatment continues in (g).

6. SOIL FERTILITY AND MANURIAL REQUIREMENTS

In the absence of a Soil Chemist results are being sent to Dr. Adams, now at Rothamsted Experimental Station, for assessment.

7. VEGETATIVE PROPAGATION

Work has been concentrated on the improvement of existing methods of rooting cuttings under polythene sheeting. The most successful method, and the one likely to give best results under farmers' conditions, is to root and harden the cutting in the same basket under a sheet of polythene. Experiments to determine the optimum periods for rooting and hardening are still in progress, but it appears at present that these will be similar to those for existing methods. A full report of this new technique is being prepared for publication.

Trials are being started to find the cheapest type of basket which can be used for rooting cuttings, but no results are yet available.

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8. PLANT BREEDING

(a) Established Trials

Harvesting was completed during the quarter. The outstanding advance in yield was from the 8th P.T.A., where some Upper Amazon and Upper Amazon x Local Selection trees have produced 30 pods during their third year in the field. Yields of the Upper Amazons in the Introductions Area have dropped slightly for the second year in succession. They have now been in the field for twelve years. Yields from the Clonal Trials are still rising and the 9th P.T.A. is in bearing after only 18 months in the field.

(b) Variety Trials on Out-Stations

Girth measurements were taken on most of these variety trials during the quarter. Hand pollinations were started to provide pods for next year's trials throughout the Gold Coast and Nigeria.

(f) Pollination Studies

i. Entomological: The identity and relative density of different pollinating insect species is being investigated by routine collections in two plots in the Square Mile; collections of approximately 100 flowers are made during different periods of the day, and any insects in the flowers kept and identified. So far (January-March), the most common insects in cacao flowers have been Cecidomyids (in 12-15% of flowers), and these possibly account for the greater part of pollination at this time of year. The three species of Ceratopogonid, discovered by Billes and Posnette, have been rare (in less than 0.1% of flowers). Both Cecidomyids and Ceratopogonids found so far have been caught in greatest numbers in the middle of the day.

An estimate of the relative numbers of flowers, and of flowers pollinated, will also be made, in order to assess the relative overall abundance of pollinating insects throughout the year. The period of the day during which most pollination takes place is being investigated.

A search is being carried out to discover the breeding sites of the pollinating insects, but this so far has been unsuccessful.

ii. Botanical: To estimate the efficiency of pollinating insects it is necessary to know whether pollen deposited at the base of the stigma is effective in causing fertilisation; this is being investigated by hand-pollinations, and the preliminary results so far obtained indicate that the stigma is receptive along its whole length, and not just at the divided apex.

9. .../

9. COCOA FERMENTATION AND QUALITY

(a) Fermentation and Chemical Constitution

(b) Effect of Drying Conditions on Purple-Bean Counts

All aspects of the work on the above projects described in recent reports have been completed, and the results are being prepared for publication. A full account will appear in the 1955-56 Annual Report.

(c) Survey of Farmers' Fermentation Methods

The returns of samples and questionnaires from Observers are far from complete, only 170 out of an expected 300 having been received.

12. PHYSIOLOGY OF NUTRITION, GROWTH AND FRUITING

(a) Root Growth

(i) While the seedlings growing on the Koforidua Soil Series showed little check in growth during the dry season, those on the Akwadum Series suffered badly and there were many deaths. Relative growth rates and net assimilation rates are being determined, so that such information as was gained by Dr. Goodall on the early growth of seedlings may be extended up to their coming into bearing.

(ii) No significant treatment effects have been noted in the experiment on the effect of over-cropping in the early years of bearing on subsequent growth and yield.

(e) Investigation of Cherelle Wilt

A large part of the quarter was spent by the Physiologist at the Isotope School, A.E.R.E., Harwell, so that radioactive tracer techniques can be applied to research on cherelle wilt. The Radiophysics Laboratory has been provided with adequate drainage and ventilating systems, and experimental work will commence shortly.

Experiments reported in the last report are being continued during the coming season, and a number of new field experiments (in addition to work involving the use of radioactive tracers) have been laid down and started :-

(i) To elucidate the effect of the 'March flush' on yield of clonal cacao.

(ii) To study cherelle wilt amongst the introduced populations, with a view to finding types showing a low percentage of wilt.

(iii) To determine the effect of large numbers of hand pollinations on the yield of cocoa, and the effect of season on flower setting.

(iv) To show the effect on yield of removing varying proportions of the developing crop.

(v) To investigate whether nutrients are withdrawn into the tree when a pod wilts.

IBADAN SUB-STATION

1. VIRUS RESEARCH

(c) Nigerian Cacao Virus Isolates

The collection of cacao virus isolates has been enlarged by addition of material from several new outbreaks discovered last quarter. The range of symptom expression in our collection is not so great as that in the collection of virus isolates made in the Gold Coast. This may reflect a true difference, possibly connected with the greater extent of the cacao-growing areas in the Gold Coast; but it may be also due to the fact that collection of infected material was started relatively recently in Nigeria.

Detailed symptom recording has been started for a number of selected isolates. Some of these produce stem swellings as the only observed symptom, others produce only leaf patterns of various types, whereas most produce both swelling and leaf symptoms. It is intended to carry out some protection tests to investigate strain relationships.

(i) Coppicing as an Adjunct to Cutting-out for the Control of Cacao Viruses

Forty-seven outbreaks of cacao virus have now been treated by coppicing, and a summary of this work and our proposals for the future were presented at the symposium held at Moor Plantation on February 17th and 18th, 1956. The work was discussed in detail and it was agreed with the Cocoa Division of the Western Region Department of Agriculture that throughout 1956 attempts should be made to control all outbreaks by treatments involving coppicing. Only infected trees are to be cut out during this period, and the surrounding area of healthy trees coppiced to a distance of thirty yards. At the end of 1956 the results will be reviewed again, and it is hoped that by then the experimental information obtained will enable definite recommendations to be made for the most efficient and economical treatment of further outbreaks.

Coppicing Experiments at I.N.A. Farm

All the proposed experiments on regeneration of cacao by coppicing have now been started, and detailed recording of the early stages of regeneration has been completed. The work to date was summarized for the Moor Plantation symposium and it is intended at a later date to write up the results for publication.

Coppicing Experiment at Owena

Half the Owena cacao farm was coppiced in June 1955, and regeneration from the stumps of severely damaged trees is being compared with recovery of similar trees which are being sprayed by the Federal Entomologist to eliminate capsids. June is now considered one of the least satisfactory months to coppice cacao in the Western Region, so the

experiment .../

experiment is overwhelmingly biased in favour of the insecticidal treatment of standing trees. Regeneration from the coppiced stumps was slow; many of the chupons were affected by the 'paint brush' condition and showed zinc and iron deficiency symptoms. Seventy-four per cent. of the stumps were surviving five months after coppicing and losses were greater than would have been expected if the trees had been coppiced during the dry season. They were scored for canopy condition (see 39th Quarterly Report) before coppicing, and the percentage of survivors in each of the categories 1, 2, 3, 4 and 5 were 82, 77, 81, 74 and 45% respectively. Comparable figures for trees in the I.N.A. experiments were 100, 96, 95, 87 and 58%. At both localities there was a tendency for losses to be confined to the most severely damaged trees.

Araromi Experiment

In May 1955, the 114 trees known to be infected and the surrounding area of apparently healthy ones at the virus outbreak at Ogo near Araromi were coppiced. To obtain information on symptom expression and the length of time which infected coppiced stumps take to produce chupons with symptoms, five inspections of the new growth have been made. The trees were coppiced at a time of year now known to be unfavourable for regeneration, so growth, particularly in the early stages, was slow. Many chupons were affected by the 'paint brush' condition and by severe iron deficiency chlorosis.

Records of the symptom observations are summarized in the Table. It will be seen that, at each inspection, the total number of stumps known to be infected was increased, by the finding of symptoms on chupons from stumps of trees which appeared healthy when coppiced. The number of stumps actually inspected for symptoms was on each occasion less than the number known to be infected, because many of the stumps died, particularly during the dry season. A feature of the results was that the number of stumps with chupons showing symptoms was always less than the number of stumps which were alive and known to be infected at the time of the inspection. All the chupons from some infected stumps were not found with symptoms until the fourth or fifth inspection, and those from one infected stump have not yet been found with symptoms. On other infected trees the chupons had leaf symptoms at the first or second inspection and were not found with symptoms on one or more later inspections.

These observations show that expression of symptoms on new growth from stumps of infected trees is very irregular, and they strongly emphasize the importance of thorough and frequent inspections to reveal all infected trees in a coppiced outbreak. The virus at Araromi usually produces leaf symptoms and swellings. The latter cannot disappear, although they may become less obvious or obscured by later growth. Even more irregular results may be expected when outbreaks are coppiced where the virus produces leaf symptoms only. If sites can be found for coppicing at a time of year known to be favourable to regeneration, further experiments on the symptom expression of chupons from infected stumps will be carried out.

SYMPTOM .../

SYMPTOM OBSERVATIONS AT THE ARAROMI COPPICED OUTBREAK

	Inspection date*				
	29.8.55	7.10.55	12.11.55	22.12.55	14.3.56
Number of stumps known to be infected	132	139	142	146	150
Number of infected stumps alive	121	120	112	103	78
Number of stumps with symptom-bearing chupons	73	81	85	92	61
Number of infected stumps living but never having shown symptoms on their chupons	48	30	15	6	1
Number of stumps with chupons showing symptoms for the first time	73	17	7	9	5
Number of stumps on which chupons have shown symptoms and then become symptomless	-	8	8	4	14

*Trees coppiced 9th May, 1955.

2. MEALYBUG STUDIES

Over 200 natural enemies of mealybugs and related insects have been sent to taxonomists in the United Kingdom. Most of these are of species already named in the W.A.C.R.I. collection, and of which the specialists concerned have requested more material. The others are of rare occurrence and have not previously been sent for identification, as no duplicates were available. Eight species of Coccinellidae and one of Aegeriidae have been named, these accounting for 28 of the specimens sent.

4. CAPSID STUDIES

Junior Staff has been trained in recording capsid damage, and assessment of canopy condition and regeneration, in preparation for the experiment on chemical control to be started in June. Labourers have been trained in the use of knapsack sprayers and mist-blowing machines. Twenty-seven

plots .../

plots in Ondo Province have been inspected and twenty-two of these have been selected as suitable for the experiment.

After discussions held with Mr. Stapley of Plant Protection Ltd. and members of the Department of Agriculture, Nigeria, the layout proposed for the experiment has been altered. The principal changes are that treatments with less than 1 oz. gamma BHC per acre have been abandoned, as have 8-weekly and 12-weekly treatments with less than 4 oz. per acre. New treatments proposed include two overall applications at four-weekly intervals followed by local applications where and when damage occurs, and the use of BHC dust. The number of replicates of each treatment has been doubled.

MINOR PESTS OF CACAO

A collection of minor pests of cacao in Nigeria has been started. Several of these have been found damaging chupons regenerating from coppiced stumps. Attacks by two of them, Earias biplaga Wlk. and Tragocephala gorilla, appear to have been fairly severe in some localities. If coppicing is to be widely applied these and other insect pests may become of major importance.

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